Fish Treadmill Investigations

Darryl Hayes, DWR

After a couple of years of physical model testing, design, construction, and major laboratory improvements, a large fish treadmill is operational at the University of California, Davis. We will use the treadmill to investigate swimming performance, behavior, and physiology of fish in a two-vector flow field. Specifically, we will use the treadmill to study:

- How different species and sizes of fish might behave at a large fish screen.
- Suitable approach and sweeping velocities and screen exposure duration for various fish species.

The cooperative project is an interagency effort. The 3-year biological testing phase is being carried out under contract with UC-Davis. The co-principal investigators are Drs. Levent Kavvas, Civil Engineering, and Joseph Cech, Fish Physiology Group. Results will be used to determine fish screen velocity and exposure duration criteria and will supplement previous treadmill tests (Technical Report 4, 1982) and fish stamina tests upon which are based the approach velocity criteria now used by DFG, NMFS, and FWS.

Treadmill experiments will focus on species of special status or perceived as weak swimmers, including delta smelt, juvenile American shad, juvenile chinook salmon, and splittail. Other fish may be tested, as time and availability of fish permit. The smallest fish expected to be monitored in the treadmill will be about 30-40mm total length.

The biological evaluation includes testing the fish in several flow regimes (approach and sweeping velocities), at 12°C and 19°C, in dark and light conditions, and with two screen orientations (vertical or horizontal wedgewire). Fish will be monitored with motion analysis video, night vision equipment, and visual observation methods. For each test, 20-50 fish will be used. The number of replicates for each treatment (*ie,* flow regime, temperature, light/dark) will be determined by the variability of measured responses. Following all experiments, fish will be monitored for 96 hours in holding facilities or collected for biochemical analyses. Observations are important to these investigations, so clear water is provided.

Fish performance and behavior will be observed and quantified through the pre-test, test, and post-test periods. Measurements will include: fish orientation (with respect to the screens, water flow, and other fish); inter-fish distances; tail beat frequencies; swimming mode ("stroke and glide" vs continuous stroking); swimming velocity (over the ground and through the water); location within the treadmill (distance from screens and depth); distance and direction traveled (through the water and over the ground) relative to the sweeping velocity; loss of equilibrium; impingement (number, frequency, duration, and behavioral responses); and mortality.

In addition, physiological responses indicating stress associated with exposure to the experimental flow regimes and impingement (including number and duration of impingements) will also be quantified using several measurements (blood/plasma: hematocrit, cortisol, lactate, and osmolality). These responses have been shown of value in making both design and management decisions for diversions and fish screens.

Fish will be acclimated, maintained, and evaluated at the UC-Davis Aquatic Center and at a new holding facility set up at the UC-Davis Hydraulics Laboratory. Both facilities have the ability to control the environmental variables using non-chlorinated, degasified, air-equilibrated well water. Large numbers of fish will be required, so these facilities are designed to accommodate as many as 2,000 fish of four species.

Experiments during the first year will focus on species and life history stages expected to be most sensitive and difficult to handle in the treadmill (*eg,* delta smelt and American shad) and extreme environmental conditions (*eg,* high approach velocity, darkness). Fish will be collected from the Sacramento-San Joaquin estuary and tributaries or from hatcheries. These preliminary tests have already begun.

The facility is designed to accommodate the various fish handling equipment, evaluation apparatus, people, and control systems. Attention to colors, lighting, noise, safety, and accessibility was integrated into the system for the biological testing.

Fish Treadmill Description

Figure 1 is a diagram of the treadmill. A swimming channel, created by a circular and rotating outer screen and an inner screen (alternative screen shapes are possible), will simulate conditions adjacent to a screened boundary in the river. Homogeneous conditions throughout the swimming channel will be achieved through its circular shape. Controlling the sweeping and approach velocities will be done by a combination of managing the rotation of the outer screen, the flow of water into

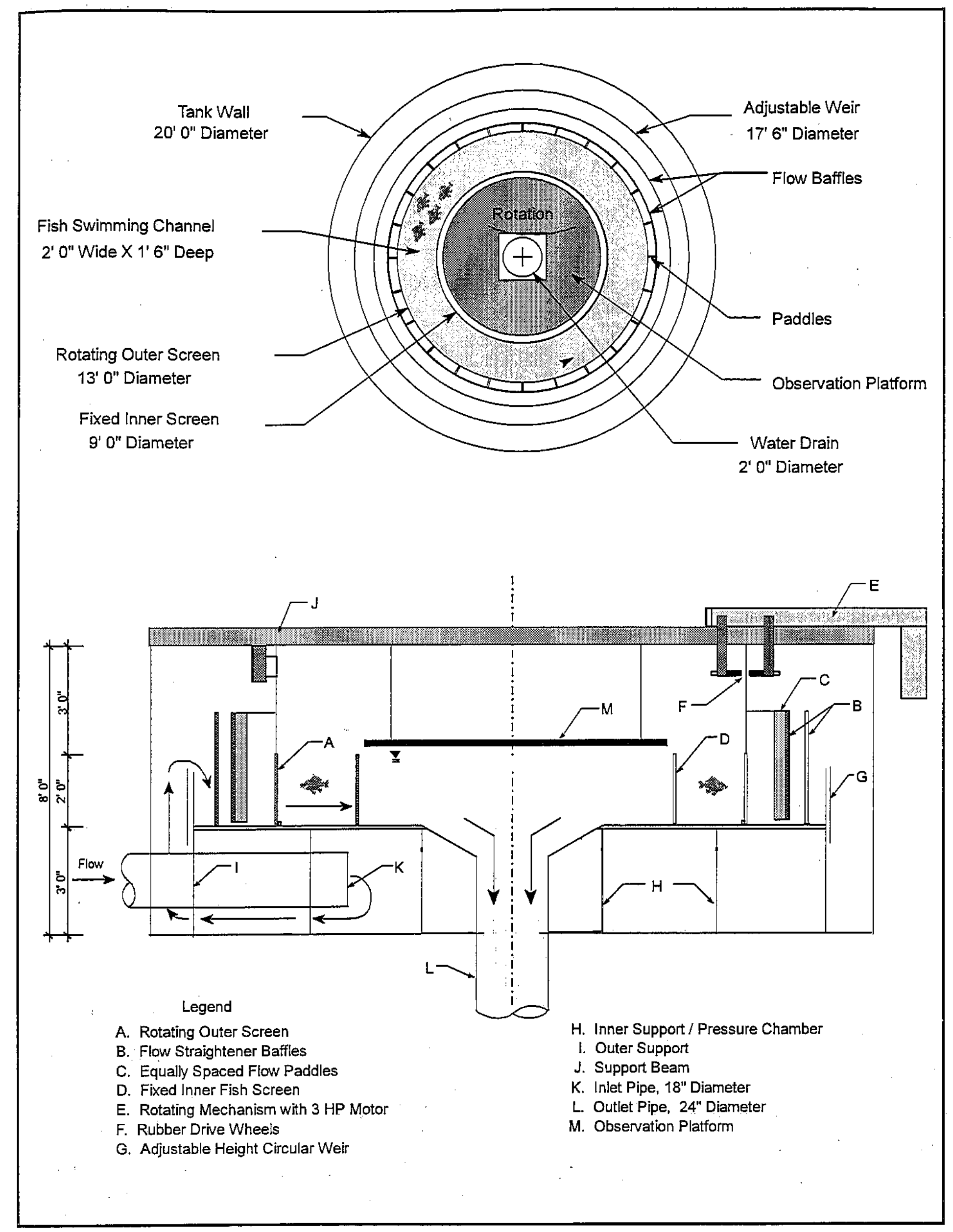

Figure 1
DIAGRAMS OF FISH TREADMILL

the tank (over the circular weir), and discharge out of the tank. Electronic monitoring equipment is used to control or measure all the hydraulic variables.

The prototype of the fish treadmill was designed based on results from a 1:2.5 scale model study and kinematic similarity laws. Much of the treadmill prototype was constructed by Gerlinger Steel & Supply Co. in Sacramento; UCD Hydraulics Laboratory technicians assembled and modified the prototype. The treadmill facility is inside the UCD Hydraulics Lab, directly above the large temperature-controlled water storage sump. The facility includes many features for fish observation, access, and operational flexibility. Fish holding facilities are adjacent to the treadmill to reduce handling time and stress.

The fish treadmill is constructed of epoxy-coated mild steel and stainless steel to avoid water toxicity and contamination to the fish. The fixed inner fish screen is wedgewire with vertically oriented 3/32-inch slots. The rotating screen is stainless steel perforated plate (3/32-inch holes) to prevent fish from escaping and provides uniform flow into the swimming channel. The driving mechanism for the rotating screen consists of two rubber wheels driven by a 3-HP motor (much like that on amusement park rides). The rotating screen is suspended from an upper support frame and has rubber rub seals at its base to form the necessary seal. This design minimizes noise and isolates vibrations. The apparatus is housed in a 20-foot-diameter outer holding tank.

The treadmill receives water from two pumps, manifolded together, which draw from a common water sump. Up to 22 cfs can be pumped through a valved 18-inch-diameter steel pipe and into two pressure chambers underneath the treadmill. This chamber dissipates the flow energy and allows uniform, tranquil water to flow over the submerged circular weir. A baffle is installed before the water enters the swimming chamber to allow further dissipation of energy and make the flow as uniform as possible. Paddles are attached near the rotating outer screen, forcing the incoming water to swirl around and into the swimming chamber. A second baffle is attached to these paddles to reduce turbulence inside the swimming chamber. Water exits the treadmill through a valved 24-inch-diameter steel pipe and flows back into the water sump. Hydraulic conditions can be controlled and easily replicated for the experiments.

This unique testing apparatus will provide insights into both fish behavior near screens and hydraulic screen design features. A DWR engineer, Jeanne Schallenberger, recently completed a study on improved screen cleaning designs using the facility. This focused study has captured the interest of screen designers across the country. As investigations get underway, we should gain a better understanding of the appropriate screen design parameters for large diversion facilities, such as those envisioned in the CALFED Bay-Delta program, or other proposed installations.

For more information on the UC-Davis Hydraulics Lab and this project, please visit their web page at: http://www.engr.ucdavis.edu/~hydlab/. If you are interested in tracking the project (via progress reports, comments, etc.), you may subscribe to an email "listserve" that has just been set up on a DFG Bay-Delta office computer server. Send an email message to majordomo@delta.dfg.ca.gov with the following line in the body of your message: subscribe fish-treadmill [your email address].

Category III

Cindy Darling, CALFED

The December 1994 Bay-Delta Accord contained a commitment to funding for fish restoration projects that addressed "non-flow" factors. This commitment was included under Section III and has become known as Category III. In the first 2 years of this program, 38 projects have been approved, using $21.7 million in contributions from urban water agencies. Funded projects include fish screens and ladders, habitat acquisition and restoration, and programs to reduce pesticide runoff. Many of the projects are partnerships with other funding sources, so the total cost of the projects approved by Category III is over $57 million.

As the program has grown and developed, the Category III steering committee has been working on a more substantial structure to select and implement projects. At the same time, $60 million in state matching funds were approved in Proposition 204, and a federal authorization passed in the closing days of Congress authorized $430 million over 3 years for ecosystem restoration projects.

The CALFED Bay-Delta Program has made significant progress on developing long-term solutions and has committed to help with immediate implementation of ecosystem restoration activities. These developments led to a decision to form the Ecosystem Roundtable to replace the Category III steering committee. This new group operates as a subcommittee of the Bay-Delta Advisory Council and includes 18 representatives of various interest groups. The mission of the Ecosystem Roundtable is to provide stakeholder input on the coordination of existing and anticipated state and federal ecosystem restoration and management programs. CALFED managers will consider input from the Ecosystem Roundtable in deciding which projects to fund for existing restoration programs and for the new sources of funding from Proposition 204 and the federal government.

The next round of projects to be funded will be selected this spring, with a final list expected in late June. In January, the Ecosystem Roundtable will suggest priority species and habitat types for this round of funding. Technical teams comprised of CALFED agency staff, academic experts, and stakeholder representatives will be working with CALFED in January, February, and March to identify the types of projects they would recommend for funding to address high priority species and habitat types. Those who would like to propose projects should look for these to be solicited in April or May. Anyone interested in submitting a proposal should send a brief letter to the CALFED Bay-Delta Program, 1416 Ninth Street, Suite 1155, Sacramento, CA 95814, asking to be placed on the mailing list.

Calculations of Required Screen Mesh Size and Vertical Bar Interval Based on Delta Smelt Morphometrics

Paciencia S. Young and Joseph J. Cech, Jr., University of California, Davis, in collaboration with Suzanne Griffin, Paul Raquel, and Dan Odenweller, DFG

We conducted a morphometric study of delta smelt to help in developing smelt screen criteria. We took morphometric measurements from preserved (10% buffered formalin) specimens and from fresh (moribund and freshly thawed) specimens. We measured again after specimens had been preserved for several months to determine a preservative-related correction factor.

Morphometric measurements from 341 preserved juvenile and adult delta smelt included: total length, fork length, standard length, maximum body depth, maximum head depth, maximum body width, and maximum head width. Total length, fork length, and standard length were measured with a Vernier caliper. Body depth, head depth, body width, and head width were measured using a Nikon Microplan II image-analyzer with IBM Microplan II imaging program. Generally, at least 30 specimens per size class (10mm intervals) over a 20-80mm TL range were used.

Preliminary results showed that many preserved specimens >40mm TL, had flared operculae so that the maximum head width measurements were greater than those without flared operculae. Some preserved specimens also had bulging eyes and some had sunken eyes. Therefore, we measured an additional 154 fresh specimens (41.1-69.9mm TL). Screen mesh size and vertical bar interval calculations followed Margraf *et al* (1985).

$$SL = (0.06564 \times M + 1.199 \times M \times F) / (1 - 0.0209 \times M)$$

where:
M = screen mesh size or vertical bar interval, and
F (Fineness Ratio) = SL/BD for screen mesh size, or SL/HW for vertical bar interval.

Table 1 provides an overall reference for delta smelt relationships among morphometric measurements in different size classes. The equations incorporate measurements of fresh specimens, corrected values of preserved specimen measurements (based on preservative-correction factor when adequate fresh measurements were not available), and uncorrected preserved measurements (on some SL measurements, when no fresh measurements were available and no correction factors could be calculated). We used body depth for calculations of maximum screen mesh size, and head width for maximum bar interval to retain specific total length and standard length of delta smelt (Figures 1 and 2). These calculations are based solely on the physical dimension (morphometrics) of delta smelt. It is assumed that fish would pass through screens lengthwise and that fish with body depth equal to mesh size would be excluded. However, three other important factors should be considered: behavior of fish in the presence of a screen;

Table 1
EQUATIONS EXPRESSING RELATIONSHIP AMONG MEASUREMENTS IN DIFFERENT SIZE CLASSES OF DELTA SMELT
Size range = 21.8-82.0.
Calculations were based on: fresh, corrected values of preserved specimen measurements; and uncorrected preserved specimen measurements involving standard length, all P<0.001.

Relationship	n	Equation	r^2
FL vs TL	324	FL = 0.608 + 0.910 TL	0.998
SL vs TL	244	SL = 0.003 + 0.840 TL	0.997
SL vs FL	242	SL = -0.439 + 0.922 FL	0.999
BD vs TL	324	BD = -0.539 + 0.147 TL + 0.00025 TL2	0.959
HD vs TL	244	HD = -0.776 + 0.133 TL	0.974
BW vs TL	244	BW = 0.095 + 0.086 TL	0.939
HW vs TL	324	HW = -2.66+0.28 TL - 0.004 TL2 +0.000028 TL3	0.849
BD vs FL	324	BD = -0.615 + 0.160 FL + 0.000314 FL2	0.958
HD vs FL	244	HD = -0.844 + 0.146 FL	0.975
BW vs FL	244	BW = 0.057 + 0.095 FL	0.937
HW vs FL	324	HW =-1.63 +0.217 FL - 0.003 FL2 +0.00002FL3	0.840
BD vs SL	244	BD = -1.086 + 0.207 SL	0.970
HD vs SL	244	HD = -1.431 + 0.194 SL - 0.0004 SL2	0.977
BW vs SL	244	BW = -0.477 + 0.132 SL - 0.0003 SL2	0.940
HW vs SL	244	HW =-3.724+0.392 SL - 0.006 SL2 +0.00004 SL3	0.881
BW vs BD	242	BW = 0.194 + 0.649 BD - 0.011 BD2	0.926
HD vs HW	222	HD = -1.290 + 1.834 HW - 0.059 HW2	0.922

TL Total length
FL Fork length
SL Standard length
BD Maximum body depth
HD Maximum head depth
BW Maximum body width
HW Maximum head width